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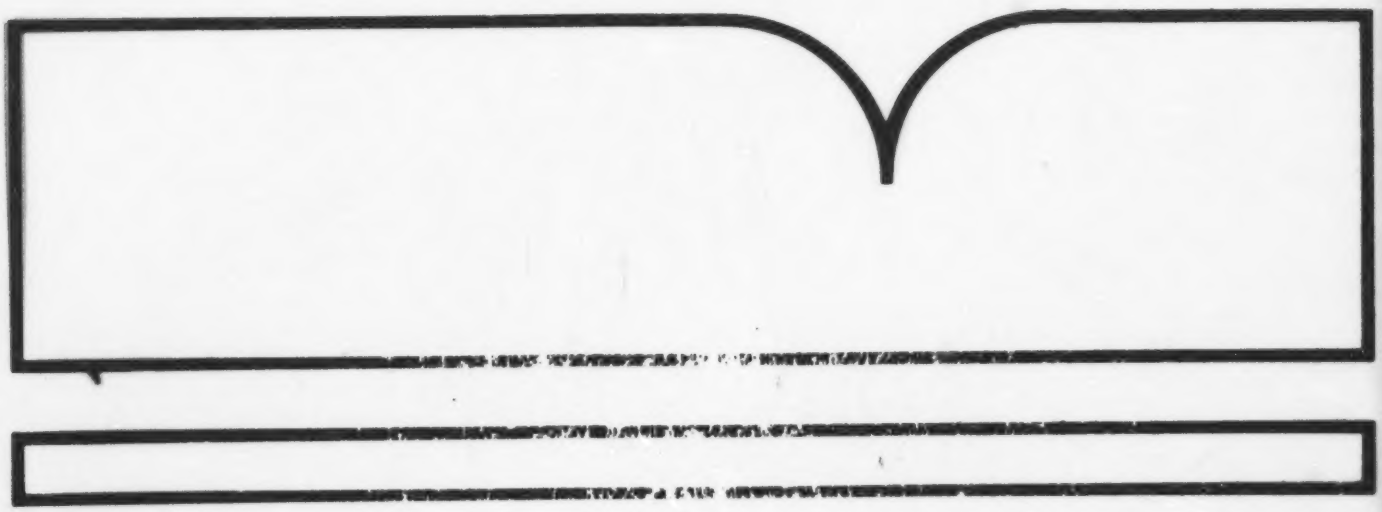

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16. ABSTRACT

A historical perspective of the need for, and the development of technology, for wastewater treatment is presented. Legislative activity for environmental enhancement closely followed public interest.

Currently, major concerns in wastewater technology are sludge disposal, control of toxic substances, and prevention of eutrophication.

Research needs in the areas of effluent compliance, pathogen survival in sludges, energy utilization, nonpoint pollution, and reduction in areal requirements for treatment facilities are discussed.

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WATER POLLUTION CONTROL TECHNOLOGY IN THE USA

by R.L. Bunch

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HISTORICAL BACKGROUND

The history of wastewater treatment development in the USA is closely associated with social attitudes. These preferences have ranged from past acceptance of foulness to current aspiration for the achievement of pristine purity. This transition in public attitudes reflects changes in the economic status of American society. Increasing affluence not only has motivated increasing solicitude for environmental quality, but also has made available financial resources for doing something about it. At the beginning of this century, the social motivation for curbing pollution rested primarily on preventing the transmission of waterborne diseases and occasionally on eliminating local nuisances. Typhoid fever was generally prevalent. While the germ theory of disease had recently been substantiated, it was not fully appreciated nor understood. Many still adhered to the popular fallacy that running water of a stream would purify itself in some seven miles of travel. A sanitary report of this period on the conditions in Chicago would refute this. This report notes that a waterway passing through the city was so fetid from waste discharge that small animals had no difficulty in running back and forth across its scum-crusted surface. Installation of filtration facilities and the disinfection of drinking water with chlorine during the early 1900s resulted in a dramatic reduction in typhoid and other waterborne diseases. Unfortunately, it also reduced the incentive for communities to support programs for wastewater treatment. Thus, the attitude that prevailed during the early part of the twentieth century was that unless an intolerable local nuisance existed or disease transmission could be traced to bad water, people were indifferent to the pollution of the water resources.

Just before the depression years (1929), there was a growing awareness that indiscriminate discharge of wastewaters from expanding industries and growing cities was creating more than just local nuisances. Many of the waterways were being made unfit for any use except as open sewers. The responsibility for pollution control, at this time, rested solely with the state governments. Federal intervention did not begin until 1948. The local and state governments rationalized that pollution was an inevitable penalty of progress. This attitude was quite prevalent during the depression years when the question was asked, "Do you want jobs or clean streams?" Despite this unfavorable attitude toward eliminating pollution, great progress was made in building of wastewater treatment plants. At that time, federal funds for public works projects became available to relieve unemployment. Within a three-year period (1933-36), 370 municipalities gave priority to treatment plants. This represented an increase of 25 percent in the number of plants previously built. It should be noted that this was done more to relieve unemployment than concern for the environment.

From 1940, there was a growing conviction that public policy for pollution should be much broader than just the prevention of nuisances and the transmission of diseases. Views were being expressed that the quality of waterways should take into account the satisfaction of a variety of social needs. The problem was how to devise a plan out of the many conflicting views that was in the best interest of the public. Eventually, it was agreed that the best way was the promulgation of water

It is with deep regret and sorrow that the Editor announces the sudden and premature death on June 8, 1982 of his dear personal friend and colleague of many years, Dr. Robert (Bob) Bunch. Dr. Bunch has been an outstanding scientist and leader in water pollution control technology. He has made many significant contributions particularly in the field of the environmental fate and effects of synthetic detergents and biodegradation of organic compounds. Dr. Bunch had represented his country in international forums such as OECD and NATO technical committees as well as in bilateral relations with many European countries and Japan. He enjoyed the highest professional esteem by his colleagues in the USA and many countries abroad. Dr. Bunch is survived by his wife Dorothy, two sons and two grandchildren. Our heartfelt sympathy goes to his family.

quality standards for waterways. Congress passed the Water Quality Act of 1965. This legislation required each state to establish quality standards for interstate waters within or on its border. Compliance for federal approval was to be by June 1967. Shortly before the deadline, federal authorities issued guidelines for standards and funds allocation. Thus, in the history of wastewater treatment development, the USA has gone from tolerating indiscriminate degradation of the waterways to one of imposing considerable restraints on wastewater discharges. The prevention of river pollution is an absolute necessity in a highly industrialized country like the USA for the maintenance of public health and general amenities. The chronology of USA wastewater treatment goals is depicted in Table 1.

TABLE 1. WASTEWATER TREATMENT GOALS

1900-1920 Historic:	Remove suspended solids Remove oxygen demanding materials
1920-1964 Contemporary:	Remove suspended solids Remove oxygen demanding materials Protect receiving water from toxicants Control coliforms
1964 Current Trend:	Remove suspended solids Remove oxygen demanding materials Protect receiving water from toxicants Control coliforms Transform NH_4^+ to NO_3^- or remove nitrogen Positive control of sludges and brines

LEGISLATIVE FRAMEWORK

The United States of America is a federal nation of 50 states, and both levels of government are involved in pollution control. The states can pass any act for controlling pollution that is not in conflict with federal laws. This means many state standards for certain bodies of water can be more restrictive than the federal standards.

Federal water legislation dates back to the nineteenth century when Congress enacted the River and Harbor Act of 1886, recodified in the Rivers and Harbors Act of 1899. It is only within the last 30 years, however, that major water pollution legislation has been passed.

In 1948, Congress enacted the Federal Water Pollution Control Act (FWPCA). This established a national policy for the prevention, control, and abatement of water pollution. The Water Pollution Control Act Amendments of 1956 stengthened enforcement provisions by providing for abatement at the request of a state pollution control agency. The federal role was further expanded under the Water Quality Act of 1965. That act provided for the setting of water quality standards which were state and federally enforceable. It became the basis for interstate water quality standards. The Water Quality Improvement Act of 1970 expanded federal authority and established a state certification procedure to prevent degradation below applicable standards. The 1972 Amendments to the FWPCA (Public Law 92-500) were the most sweeping.

The Federal Water Pollution Control Act Amendments of 1972, which were amended in 1977 and 1978 (commonly known as the Clean Water Act), changed the thrust of enforcement from water quality standards to effluent limitations, i.e., regulating the amount of pollutants being discharged from particular point sources. The Act also set two goals. The first national goal is the elimination of discharge of all pollutants into the navigable waters of the United States by 1985. The second national goal is an interim level of water quality that provides for the protection of fish, shellfish, wildlife, and recreation by July 1, 1983. The act established a nation-wide system of permits aimed at controlling the discharge of pollutants from point sources into the nation's waterways. No discharge of any pollutant from any point source is permitted without a permit. The regulation applies to all industrial discharges, publicly owned wastewater works, and municipally controlled discharge points. All municipal effluents must meet the equivalent of secondary treatment. The effluent reduction attainable by secondary treatment is expressed in terms of biochemical oxygen demand (BOD_5), suspended solids (SS), and acidity-alkalinity (pH). For BOD_5 and SS, the regulation calls for a maximum monthly average of 30 mg/l and a maximum weekly average of 45 mg/l. The effluent pH must be within the range of 6 to 9.

Under authority of Section 307(b) of the Federal Water Pollution Control Act Amendments of 1972, the U.S. Environmental Protection agency (EPA) has issued "Pretreatment Standards". The standards apply to all non-domestic users of publicly owned treatment works. The standards are designed to prevent the introduction of incompatible pollutants to publicly owned treatment works which would pass through such works inadequately treated. Any pollutant, other than biochemical oxygen demand, suspended solids, pH, and fecal coliform bacteria, is by definition incompatible.

In response to an international agreement, the Congress passed

the Marine Protection, Research, and Sanctuaries Act of 1972 (MPRSA). Its purpose is to prevent or limit ocean dumping of any material that would adversely affect human health, ecological systems, or economic potentialities. In practical terms, the Act is intended to stop all harmful dumping by 1981.

The Toxic Substances Control Act (TSCA), passed by the Congress in 1976, represents one of the most comprehensive and complex regulatory programs ever attempted by the federal government. The potential impact of toxic substances on the population is tremendous. There are more than four million chemical substances in existence, tens of thousands in commerce, and thousands of new ones introduced each year.

The USA has now established guidelines for employment of pollution control technology and set target dates for achieving fishable, swimmable waters. These laws encourage productive and enjoyable harmony between man and his environment.

WATER POLLUTION CONCERNS

The major water pollution concerns are: (1) sewage sludge disposal, (2) toxic substances, (3) control of pathogens, (4) eutrophication, and (5) treatment plant performance.

Sewage Sludge Disposal

Handling and disposing of sludges are the most troublesome aspects of wastewater treatment. The cost of sludge disposal in the USA presently amounts to about 50 percent of the treatment cost. Currently, municipal sewage treatment plants produce about 4.5 billion kilograms of dry sludge per year. This amount is expected to double in the next ten years due to the increase in the volume of wastewater to be treated, implementation of secondary wastewater treatment, and removal of phosphorus from effluents in discharging into the Great Lakes. The magnitude of the problem can be seen in the operation of the Metropolitan Sanitary District of Greater Chicago which serves 5.4 million people plus a nondomestic equivalent of 4.5 million. The District's several wastewater treatment works produce more than 670 tonnes of sludge daily on a dry basis.

Disposal of sludges on land, in lagoons, or in the ocean are the cheapest methods of disposing of sludge, provided that suitable land or the oceans are within economical range of the source. The major methods of sewage sludge disposal in the USA are: landspreading (31 percent), landfilling (24 percent), incineration (21 percent), ocean disposal (18 percent), and composting (1 percent). The options for sludge disposal have been limited by the enactment of recent regulations. The FWPCA of 1972 (as amended) requires mandatory secondary treatment for all municipal wastewaters. Secondary treatment creates more sludge needing disposal, and the cities and towns of the Atlantic Coast have increasingly used the ocean for disposal. In 1977, the Congress amended the Marine Protection, Research, and Sanctuaries Act of 1972 to stop all harmful dumps by December 31, 1981. This has created a real burden on larger cities, like New York City, to find alternative ways of disposing of their sludge.

Landspreading of sludges is a desirable option for the disposal of sludge. Sludge contains plant nutrients and is a valuable supplement to chemical fertilizer when used with proper management. The use of sewage sludge on cropland is limited by several factors, but the most important are the nitrogen content, concentration of metals, and the survival of pathogens. Under authority of the Resource Conservation and Recovery Act and the Clean Water Act, criteria for sludge application to land have been issued (1). The regulation focuses on the hazards from pathogens and toxic metals in sludge. Raw sludge without treatment cannot be utilized or disposed on land. Sludges that have been subjected to a process that "significantly reduces pathogens" can be used with certain restrictions. Sludges which have been treated to "further reduce pathogens" have no disposal restriction insofar as a pathogen parameter. There are criteria for sludges containing cadmium and polychlorinated biphenyls (PCB). The cadmium limit applies to various crops, annual application, and cumulative amount. The PCB restriction applies to animal feed crops, including pasture crops for animals for milk production.

Landspreading of sludge, if done properly, can be environmentally safe, reasonable in cost, and acceptable to the public.

Toxic Substances

The development of a highly industrialized country is usually accompanied by the proliferation of chemicals for many uses. Chemicals initially synthesized to meet the technical requirements of a new product frequently become widely proliferated among hundreds of products. Chemicals are invaluable to society, and most are believed relatively safe under normal conditions of use. The concern is that many chemicals have proven to be harmful, and the health effects of many are unknown. Controlling toxic substances in wastewater and sludges is presenting a new challenge. Over 1300 organic chemicals have been found in the surface waters of the USA (2). The list is expanding rapidly as analytical techniques are refined and surveys are conducted.

Mounting public concern over

effects of toxic compounds made it imperative that the Federal government act swiftly to enact the Toxic Substances Control Act in January 1977. The Act seeks to control hazardous chemical substances at their sources before they are dispersed into the environment. The approach will be to require pretreatment by industry of wastes that inhibit or interfere with the treatment of municipal wastewater, including contamination of sludge which would make it unsafe for use as fertilizer. EPA's toxic pollutant control program is proceeding under a time table established in a settlement of a suit brought by the Natural Research Defense Council (NRDC) versus Train (3). Specifically, the Settlement Agreement directed EPA to develop effluent guidelines for toxic substances employing Best Available Technology Economically Achievable (BATEA) for 21 primary industries no later than December 31, 1979. Actually, there are over 280 subcategories for which performance standards must be set. The court also directed EPA to issue water quality criteria for 65 classes of toxic pollutants. The 65 classes include 129 separate substances (see Table 2). The dates for both decrees have been extended to permit EPA to develop standards and guidelines.

The pretreatment discharge standards are of two types. First are the general regulations that apply to all discharges without distinguishing among industries. The second type is the categorial pretreatment standards developed on an industry-by-industry basis. These standards contain numerical limitations on the quantities of particular pollutants which may be discharged by any plant in a designated category. The standards are expressed as either a concentration, such as mg/l of pollutant in the discharge, or as mass weight per unit of production. It is estimated that at least 87 000 industrial plants, classified in the 21 "primary" industries, use publicly owned treatment works to process their wastes. The method of enforcement of pretreatment limits on industries is of great concern. EPA will have to rely heavily on local municipalities to enforce the limits.

Control of Pathogens

One of the main reasons for treating wastewater is to prevent the spread of diseases. Many of the cities in the USA depend on surface waters for their drinking water supply. Intakes for water supplies were originally located upstream from discharges of waste from cities. With increasing population expansion along our waterways, many downstream towns' water supplies contain wastes from upstream communities. While water treatment technology can successfully process poor quality source, there is serious concern that the barrier to microbial breakthrough in the finished water may be dangerously small. The presence of viruses in sewage and in rivers has recently drawn much attention. Several varieties are more resistant to disinfectants than pathogenic bacteria.

The disinfection of treated wastewater before discharge to surface waters and of sewage sludges before landspreading is a controversial procedure. Disinfection of treated wastewaters and sewage sludges is not routinely practiced in Europe to the extent that it is in

TABLE 2. 65 TOXIC POLLUTANTS LISTED IN CONSENT DECREE

Acenaphthene
Acrolein
Acrylonitrile
Aldrin/Dieldrin
Antimony and compounds
Arsenic and compounds
Asbestos
Benzene
Benzidine
Beryllium and compounds
Cadmium and compounds
Carbon tetrachloride
Chlordane
Chlorinated benzenes
Chlorinated ethanes
Chloralkyl ethers
Chlorinated naphthalene
Chlorinated phenols
Chloroform
2-Chlorophenol
Chromium and compounds
Copper and compounds
Cyanides
DDT and metabolites
Dichlorobenzenes
Dichlorobenzidine
Dichloroethylenes
2, 4-Dichlorophenol
Dichloropropane & Dichloropropene
2, 4-Dimethylphenol
Dinitrotoluene
Diphenylhydrazine
Endosulfan & metabolites
Endrin and metabolites
Ethylbenzene
Fluoranthene
Haloethers
Halomethanes
Heptachlor & metabolites
Hexachlorobutadiene
Hexachlorocyclopentadiene
Hexachlorocyclohexane
Isophorone
Lead and compounds
Mercury and compounds
Naphthalene
Nickel and compounds
Nitrobenzene
Nitrophenols
Nitrosamines
Pentachlorophenol
Phenol
Phthalate esters
Polychlorinated biphenyls (PCBs)
Polynuclear aromatic hydrocarbons
Selenium and compounds
Silver and compounds
2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD)
Tetrachloroethylene
Thallium and compounds
Toluene
Toxaphene
Trichlorethylene
Vinyl chloride
Zinc and compounds

North America. Until 1972, the disinfection requirements in the USA varied widely from state to state. Seasonal disinfection of wastewater was practiced in many states, while no disinfection was required for certain where the possibility of human contact was remote. With the passage of the Federal Water Pollution Act Amendments of 1972, national effluent standards for industrial and municipal wastewater discharges were established. Included in the effluent standards were biochemical oxygen demand, suspended solids, pH, and fecal coliform bacteria. The limit on fecal coliform bacteria was set at 200 per 100 milliters. On July 26, 1976, the fecal coliform requirement was deleted from the effluent standards. Reliance on each state to set disinfection requirements based on site-specific water quality standards is now the practice. Thus, disinfection is still required by state regulation, but no uniform federal requirements have to be achieved.

The adverse environmental effects of residual chlorine and chlorinated hydrocarbons in chlorinated wastewaters and sludges has prompted the search for alternative disinfection agents which would satisfy the disinfection requirements and be environmentally acceptable. The present alternatives currently under investigation are: chlorination-dechlorination, ozonation, and application of ultraviolet light for wastewater; irradiation and pasteurization for sludge.

Eutrophication

Increasing attention worldwide is being focused upon the excess enrichment or eutrophication of natural bodies of water, such as lakes, reservoirs, sluggish streams, and estuaries. It is well known that nutrients, such as nitrogen and phosphorus, are required for algae growth. Sewage contains an abundance of both nitrogen and phosphorus. Phosphorus is found to be critical in terms of extensive production more frequently than nitrogen. Upper San Francisco Bay is a situation where nitrogen control must be used for control of eutrophication because it has been demonstrated that nitrogen is the critical element. In the Potomac Estuary during the summer and in the James River Estuary, nitrogen also appears to be the limiting factor. The Great Lakes are a prime example of sewage nutrients increasing the eutrophication rate. Under the Great Lakes Water Quality Agreement of 1972 between Canada and the United States, both governments agreed on the necessity for a 1-mg/l limit for phosphorus for all municipal treatment plants which discharge more than 3785 m^3/d of wastewater into the Great Lakes. While eutrophication has been slowed, the rate is still more than the natural rate. For this reason, the two countries are now considering lowering the phosphorus effluent limit and extending it to all municipal plants.

The trend of eutrophication has been reversed in Lake Washington in Seattle and in the Madison Lakes in Wisconsin by diverting the wastewater treatment plant effluents from these lakes. Lake Tahoe has been preserved by removing the phosphorus by tertiary treatment. Although the above are excellent examples of improvements, the fact remains that more than 80 percent of the 3700 urban lakes in the United States have some pollutional problems. There are no national laws controlling the amount of phosphorus and nitrogen in wastewater discharges. Many states and local municipalities have set limits. In many locations, the amount of phosphates in detergents has been limited. Noticeable examples are Erie County in New York State and the State of Indiana.

Treatment Plant Performance

The 1972 Amendments to the Federal Water Pollution Control Act established July 1, 1977, as the deadline for all publicly owned treatment works to be using secondary treatment and all industrial facilities to be using the "best practical" pollution control technology. Only about 40 percent of the major municipal discharges actually met the conditions of the law on July 1, 1977. Results in industry were better; approximately 80 percent of the major discharges were in compliance. The country underestimated the length of time it would take to design, construct, and put in operation all the facilities needed in the USA.

Existence of a municipal wastewater treatment plant does not guarantee cleaner water. EPA has become increasingly aware of operation and maintenance (O&M) problems of existing plants. All too often, a particular plant does not or cannot operate according to design specifications for the lack of skilled operators, chemical supplies, replacement parts, or periodic inspections. EPA's annual inspection survey of 1977 found that only 50-55 percent of the plants examined were operating at a near-design specification for removal of biochemical oxygen demand. Larger plants were generally more fully staffed, funded, and repaired than small ones.

EPA is working to increase federal, state, local, and private efforts to improve plant performance. There is a need for more federal or state attention to enforcement of municipal permits in order to insure that facilities fully meet their O&M responsibilities. The penalties for poor performance have in the past been so low or non-existent that little incentive for maintaining proper performance existed. The condition is now changing.

WASTEWATER TREATMENT CAPABILITY

About 160 million people in the USA are served by some type of

central treatment facility, while 60 million have either no treatment of their wastes or utilize on-site units, such as septic tanks. In, 1978 there were 21 710 municipal wastewater facilities with a total daily flow of 83×10^6 m^3. About 65 percent of these facilities are less than 3785 m^3/d in design flow. Fewer than 350 are larger than 37 850 m^3/d. The number and classification of treatment facilities are shown in Tables 3 and 4.

TABLE 3. MUNICIPAL WASTE TREATEMENT IN USA

Total population	220 000 000
Total area	9 363 123 km^2
Population density	24 persons/km^2
Sewered	73%
No treatment or on-site units	27%
Treatment	71%
primary	23%
biological	75%
advanced	2%

TABLE 4. MUNICIPAL WASTES FACILITIES IN 1978

Facility type	Number	Persons served
Activated sludge	5109	61 000 000
Trickling filter	3270	31 500 000
Oxidation pond	4800	12 000 000
Miscellaneous	2446	9 500 000
Rotating disc	60	2 000 000
Primary treatment	2377	36 000 000
Raw discharge	2603	3 600 000
Tertiary	1045	4 400 000
Total facilities	21 700	160 000 000

TECHNOLOGY GAP

Instrumentation and control have not yet caught up with the basic requirements of wastewater treatment plants. The cost of instrumentation in a fully automated chemical plant will run between 10 and 15 percent of the plant cost. This is considerably more than the present usage in wastewater tratment plants, even those run by industry. Presently, reliance for satisfactory performance is placed on the knowledge and skill of the operator backed by equipment developed to suit specific plant requirements. The nature of biological wastewater treatment processes differs substantially from "industrial processes" where "endpoint" control criteria are well known. In industrial processes, automation permits end product maximum quality control. Wastewater treatment plants must accept material as received and treat it empirically to produce an effluent which meets "minimum" standards. Techniques need to be developed to measure biological actions to control flow reactions.

Very little is currently known about the fate of organic pollutants in sludge applied to the land, their effect on crops, rates of degradation or movement to groundwater. A few studies have been done on pesticides, but little or no work has been devoted to the vast number of other potentially significant organics. There is a need for comprehensive studies designed to develop environmental fate models for chemical pollutants. It would be an enormous task to develop data for all the 70 000 different chemicals used in the USA as to their behavior in the environment or in unit processes. With enough basic information on treatability, it may become possible to develop models from which the behavior of untested compounds can be predicted.

Bacteria, viruses, and parasites associated with wastewater and sludge applied to agricultural lands present potential health problems. Conjecture as to the potential health effects of sludge applied to the land has been extensive, although data and risk interpretations are limited. More studies have been done on bacteria and virus persistence in soil than with parasites. Relatively little is known about the possibility of parasitic disease transmission by the way of sludge-amended soils. Parasitic ova and cysts are quite resistant to common disinfection practice and adverse environmental conditions.

The degree of risk to human health from pathogens in sludge is not known and may never be adequately defined. Landspreading will probably never be done if one waits for an absolute answer. Past experience has shown that anaerobically digested sludge, when properly used, is not a threat to public health. There exists a gap in information on the pathogen densities of various sludges processed by various stabilization processes. They should be determined and compared to anaerobically digested sludge.

Nonpoint source pollution is increasingly recognized as a major challenge in cleaning up the waterways of the USA. Nonpoint sources are usually diffused and hard to control. Important nonpoint sources are: agricultural activities, urban storm water runoff, mining runoff, silviculture, and individual wastewater disposal systems. Contrasted to the great progress made in the seventies in controlling industrial and municipal wastes, negligible progress has been made in nonpoint source control. If the nation is to achieve its clean water goals, nonpoint sources must be controlled.

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The second biggest polluting discharges in industry are linked with the processing of sugar beets. Workable solutions for wastewater treatment have been developed for 3 out of 6 mills. These solutions differ from mill to mill.

One internally closed sugar mill is situated close to a central treatment plant designed for extended aeration. By installing a bigger aeration capacity than needed for extended aeration alone and by disposing of the excess sludge during the processing season of sugar beets together with the topsoil of the beets close to the mill, it was possible to find a practicable solution without the necessity for large investments.

Another mill is not yet closed since the mill managers feel that they run in such a way a much more reliable operation. Unfortunately, water available for processing - predominantly for fluming of the sugar beets - will be limited in the future. The processing season of sugar beets in Austria normally lasts from the beginning of October through the end of December. The solution found at this mill was to have the mill effluent enter an extended aeration plant that serves for biological treatment and cooling as well. The treated effluent is used for fluming again.

Regarding industrial discharges other than from pulping, there is success; but many problems still remain to be solved.

PROTECTION OF LAKES

Top priority has been given to the protection of many lakes. It was felt that the most reliable method of taking care of point-source discharges was the erection of collectors from the end of a sewer system to a wastewater treatment plant at the natural outflow of a lake. Such quite costly proposals have materialized in Carinthia (Faaker See, Millstatter See, Ossiacher See, Weissensee and Worthersee, to name but a few big ones) as well as in Upper Austria (Attersee, Traunsee) and in Salzburg (Wolfgangsee, Zellersee). The collected wastewater is treated biologically in central wastewater treatment plants; phosphorus however, is not removed. In the drainage areas of Lake Constanze in the west as well as Neusiedlersee in the east, simultaneous precipitation - mostly with twovalent iron - is practiced.

Most of these decisions to invest were based on emotion and not on nutrient budget approach. It seems, however, with the exception of Lake Constance and Neusiedlersee, that the point-source load contributes by far more than the nonpoint-source. From this consideration such an approach was justified.

For the basin of Neusiedlersee, a nutrient budget approach was undertaken. Treatment plants existed at many locations; the topography was such that the water had to be lifted by 60 and 100m, respectively, in order to be pumped into the drainage basin of the Danube on Austrian Territory. The budget for total phosphorus revealed that in the case of simultaneous precipitation with bivalent iron, the nonpoint-source discharges outweigh the point-source discharges at a ratio of 10 to 1 to 20 to 1, depending on the iron dose. From a cost-effectiveness as well as from an implementation point of view, basin transfer was felt to be totally inappropriate. The treatment plant control scheme mentioned in the section on Domestic Wastewater Pollution Control is part of the solution proposed for Neusiedlersee.

SUMMARY AND CONCLUSIONS

Water pollution control technology applied in Austria relates to its overall historic development as well as to the current practices. Future developments in the water pollution control technology in Austria will be influenced by (i) internal as well as external methods of wastewater treatment of industrial wastes; (ii) the demands of the drinking water supply side on the water quality of receiving waters; (iii) the pressure imposed on Austria by downstream users; and (iv) enlightened changes in application of the austrian Water Law.

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TRENDS IN TECHNOLOGY DEVELOPMENT

The main thrust of technology development in wastewater treatment will be in the arena of combating the effects of inflation. In contrast to the preoccupation with improving existing technology in the past, attention and resources will be directed toward novel process development with breakthrough potential in the areas of cost reduction (construction cost, energy requirement, manpower), reduced space requirements, reduced sludge production, improved efficiency, and conservation of natural resources.

With the rapidly increasing emphasis on the environmental acceptability of effluent discharges, newly developed processes will have to be capable of removing organic and trace contaminants other than the conventional pollutants and to rely on pretreatment or post treatment for removal of toxic and unconventional pollutants.

Recent emphasis on water quality standards in the USA and the increasing cost of manpower will place more reliance for satisfactory performance of wastewater treatment plants on instrumentation. The design of new treatment plants will require a considerably broader knowledge of treatment and control. Early consideration of automated control strategies for new processes

will enhance the potential for efficient operation and performance. Centralized management and operation is likely to be the most cost effective mechanism for providing effective operation and maintenance of small plants. The development of microprocessor and minicomputer systems for monitoring, process control, and remote data transmission will be essential for efficient centralized management of operation and maintenance.

Sludge and residue disposal will continue to be a major problem in the treatment of domestic and industrial wastes. Disposal without readmission of hazardous components to the air, water, or soil media constitute immediate and future problems. Currently, no disposal method is without some environmental impact. Incineration at sea holds promise for safe disposal of highly toxic industrial wastes and sludges. This will probably become a major alternative to land-based incineration and ocean dumping. The most impressive use of this innovative technology was the combustion of 7500 m^3 of herbicide Agent Orange at a site 1280 km west of Hawaii. The destruction was more than 99.99 percent complete, and there were no detectable adverse effects on the personnel aboard ship or the environment. The feasibility of ocean platform incineration is being studied. The management of municipal sludges will be switched from energy-intensive processes to landspreading, composting, and obtaining other useful products, such as liquid and gaseous fuels.

Solar energy will play a larger role in wastewater treatment. Pumping of wastewater to lagoons and to irrigation projects will be practiced. Anaerobic digestors will be heated by solar energy, thus freeing the methane for higher grade energy requirements. Studies have shown that plate solar collectors can provide from 82 to 97 percent of the total annual digester heat load. Heat pumps will become common place at wastewater treatment works.

Major impediments to monitoring toxic substances will need to be overcome. The present analytical procedures, which are complex and costly, will need to be replaced. While the capability does not now exist, there is a substantive long-term need for surrogate methods, both for measuring toxicity and for evaluating the ability of treatment technologies to reduce toxicity.

Many have voiced an opinion that you cannot have industrial progress without polluting the environment. Recent progress indicates the opposite is possible. You can have industrial progress without increasing pollution to an unacceptable level. This is an exciting challenge for not only developed nations but for the developing nations as well. Past experience indicates that it is far wiser and cheaper to preserve a body of water rather than to save a body of water.

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use of instruments and microprocessors, mostly to provide information for the plant manager, with some local control of specific physical processes, such as aeration. It is unlikely that full automation will be applied to biological processes.

Finally, looking at the whole of sewage and sludge treatment, we now have a mathematic model, the Sewage Treatment Optimization Model, which can be used as an aid in operational control and trouble-shooting, and in design. If the sizes of the various process units are specified the effluent quality is predicted. If the effluent quality is specified, the model calculates the optimum size of each process unit to give the minimum total annual cash flow. The model has been constructed on the basis of data from the UK, but it is hoped to extend it so that it will, for example, deal with treatment in warmer or colder climates.

It is hoped that the trend will be towards greater use of such models with readily available microprocessors.

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